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FOE OF CORROSION

FREDERICK W. FINK

"Corrosion, like leprosy, is something we may not like to think about. All the more credit to those firms that face up to their corrosion problems before they suffer serious damage. Sometimes, the specialist is not called until corrosion's deadly work has a long start. Then something has to be done in a hurry." Thus corrosion technologist Frederick W. Fink points out the importance of continually fighting corrosion and concludes: "By working at it steadily, industries can cut needless losses which now total hundreds of millions of dollars yearly".

Fighting corrosion is Fred's life work. He entered it quite naturally. After earning his degree in electrical engineering from Cornell University, he studied at Cambridge University in England. There he came under the spell of the noted corrosion expert, Ulick R. Evans, author of the "bible" of corrosion. What was to be an academic course ended in a master's degree and a career.

Corrosion is a meeting ground of several sciences, including physics, metallurgy, chemistry, and electrochemistry, and Fred and his associates deal with all of them. Since his association with Battelle in 1938, he has helped to develop corrosion-resistant alloy castings and nonferrous alloys and various types of protective coatings. He has worked on such problems as cathodic methods of protection, corrosion-proofing of fire extinguishers, and corrosion inhibitors. A special interest is the use of light metals in marine applications. At the close of World War II Fred received the Naval Ordnance Award for his work on problems of marine corrosion.

The shortage of metals and use of alternative materials made the study of corrosion extremely significant during World War II. Once the value of corrosion control was recognized, the growth of the field was rapid. Fred advanced with his field. This year he is chairman of the important Corrosion Division of the Electrochemical Society. Earlier he was chairman of the Gordon Corrosion Conference of the American Association for the Advancement of Science.

Away from his laboratory, Fred spends much of his time on his three children, his home, and music. Both he and his wife have maintained close contact with European friends, and the entertainment of foreign visitors is one of their great pleasures.

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Saving Research Manpower

NEARLY EVERYONE who has studied the technical manpower shortage agrees that there is little hope for supply catching up with demand before 1960. This means that during the rest of this decade every means possible will have to be used by science, industry, and the military services to make our supply of research scientists go further.

Greater care in research planning so as to eliminate unnecessary work is one way to extend the services of our research people. It has been estimated that only about one research project out of every ten undertaken turns out to be completely successful in the economic sense. Research must, of course, always be bold and venturesome, but obviously there is room for improvement without stifling the spirit of scientific inquiry. There are about 140,000 scientists and engineers now employed in research and development work in industry, universities, and government laboratories. If, through careful planning of research, we could reduce the work of research people by 10 per cent, we would achieve the same effects as adding 14,000 men to our research force. This is nearly as many people as our engineering schools will be graduating a few years hence.

An obvious method of conserving scientific talent is to use it to best advantage. There is no point in employing engineers and scientists to handle routine tasks or assignments outside their fields of specialization. Technical and nontechnical assistants can take over many laboratory and desk duties and free trained research personnel for creative work. The increased use of skilled craftsmen, librarians, editors, writers, patent attorneys, economists, illustrators, and other competently qualified personnel in those functions of research calling for their specialized knowledge and skills will also give the scientist greater working capacity. In a well-knit laboratory today, there is little need for a scientist to be an experimenter in the crafts or nonscience disciplines.

More intensive use of technical libraries will add to the productivity of our research staffs. Too often experimental procedure is undertaken without adequate review of the literature. Yet, the mass of material in our libraries represents work already accomplished—the experience of others. We can use this experience to save critical manhours. We should learn to use it economically.

The improvement of research efficiency through greater care in planning, the use of assistants and supplementary personnel, and the elimination of needless work will justify higher salaries for research people. This in turn will automatically encourage more high school students to enroll in science and engineering courses in our universities. Thus, the expediencies undertaken today to conserve technical manpower will be prime factors in bringing about a lasting solution to our problem.

Clyde Williams

Director, Battelle Memorial Institute

Better Fabrics for the Future

by LARRY C. LEATHERLAND

The author has written a number of technical publications in the textile field. Before joining Battelle in 1952, he was general superintendent of the chemical division of the Virginia-Carolina Chemical Corporation. Earlier he was directing head of the engineering departments of the Institute of Textile Technology and associated with the Sylvania Division of the American Viscose Corporation.

THOSE WHO SAW the recent British movie, "The Man in the White Suit", were presented one view of fabrics for the future. After many "bloop-bleeps" of the pilot-plant production unit, and a few explosions, the true "miracle" fiber was born. The fabric woven from it was cut into patterned shapes by means of a blowtorch, and made into a man's suit by electric welding of the seams. The result was a soil-proof, water-proof, fire-proof, wear-ever suit; that is, until it unexpectedly disintegrated. According to the movie, the inventor is still at large and thinks he knows what went wrong with his new "wonder" fiber.

When viscose rayon was first produced it was an attempted substitute for silk. The early struggles to overcome its shortcomings are well known. Manufacturers of the newer fibers have avoided such difficulties by letting each new fiber stand on its own feet. As a result, these fibers have been used where their good qualities dictated. Knowledge and understanding of these good qualities will lead the way to better future fabrics of any fiber.

The growth of the synthetics has had two definite effects on the natural fibers. The first effect has been loss of markets for natural fibers. Data from the September, 1952, issue of *Textile World* tells part of the story of the first effect by comparing consumption figures for 1930 with an estimate of consumption in 1953:

RELATIVE FIBER CONSUMPTION IN THE U. S.

	1930	*1953 (estimated)*	*% Change*
Cotton	85%	70%	— 18%
Wool	9	6	— 33
Synthetics			
Cellulosic*	3	18	+700
All others	0	6	+700
Silk	3	0	—100

*Includes acetate and viscose rayon.

As the given data show, cotton consumption has decreased appreciably; wool drastically; and silk has disappeared for all practical purposes. The rayons, viscose and acetate, have replaced cotton in a part of the clothing and tire-cord fields. Some of the synthetics have replaced it for other industrial uses. However, cotton will probably always retain most of the market because of its low cost and the breadth of its usefulness.

The impact of synthetics on wool has been serious. A large part of this impact has been the result of the nature of the wool industry. Fluctuating prices of raw materials and rapidly changing demands of consumers often made the existence of wool manufacturers a precarious one. Therefore, it was not strange that with the introduction of synthetics with their more stable prices, many manufacturers turned to the new fibers. Neither laws nor advertising have been successful in halting the decline in the use of wool.

The second effect of the growth of the synthetics on natural fiber has been the trend toward processing of the natural fibers to decrease or eliminate their undesirable properties. While cotton, wool, and silk ruled the textile world, the consumers and industrial users learned to live with the undesirable properties of these natural fibers. Each fiber had become established according to its own particular properties. None was actually in competition with the other two. Therefore, no real incentive existed for improving any of them. Levis and wool shirts were bought two sizes oversize and shrank when they were wet. Dresses and curtains had wide hems. White shirts soiled and rumpled quickly. The consumer took this whether he liked it or not. Now, synthetics are changing the picture. They have many of the good properties of the natural fibers, without some of their bad ones. By taking steps to eliminate the undesirable qualities of the natural fibers, the industry demonstrates its health by looking aggressively to the future.

Shrinkage Control

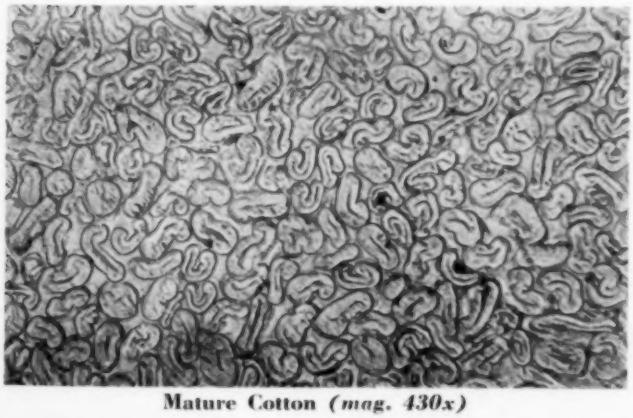
Shrinkage was probably the first undesirable property of the natural fibers to be improved. "Sanforizing" became a common word. This is a mechanical process in which the yarns of cotton fabrics are pushed together longitudinally so that future shrinkage of the fibers has very little effect on the over-all dimensions of the cloth. This system has worked well on cotton fabrics, but not on rayon. Probably the earliest successful process for rayon was developed by Tootal Broadhurst Lee Company in England. This process was based on forming resins inside the cloth. Fabrics processed in this manner had reduced residual shrinkage and improved resistance to wrinkling or creasing. Since the development of this process, many types of resins have been used; but urea-formaldehyde and melamine-formaldehyde are probably the principal ones in use. The process can be applied to cotton, as well as rayon, goods. However, it has a serious drawback in that it weakens the fabric. The percentage of strength lost is usually greater for cotton than for rayon.

Many recent attempts to make cotton and rayon shrink-resistant have been based on reactions between the cellulose of the fabric and formaldehyde. On the theory that shrinkage resulted from cellulose chains within the fibers slipping along one another, it seemed possible to reduce this slippage by locking together adjacent chains. Formaldehyde apparently did this. The exact nature of the formaldehyde "lock", or "bridge", has not been fully defined, although Pacsu and others have contributed much to its understanding. This seems to be a true chemical modification of the basic cellulose of the fiber. Glyoxal, and other chemical compounds which would decompose into formaldehyde, have also been used for this purpose.

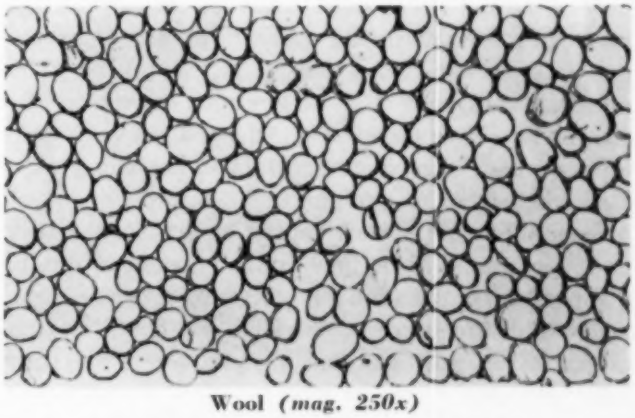
Shrinkage control of wool has presented a different problem. Microscopic examination of wool fibers shows that their surfaces are covered with scales. The scales on one fiber all point toward the same end of the fiber, roughly comparable to the teeth on a wood rasp file. Therefore, fibers can slip against each other more easily in one direction than in the other. It is this property which allows wool to be compressed into a felt pad. This property also allows wool to shrink.

FIBER CROSS-SECTIONS

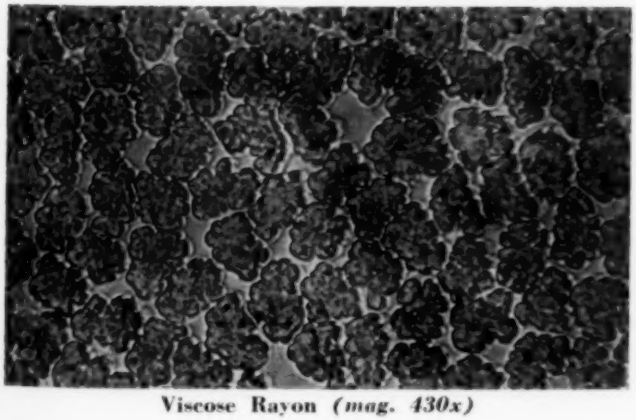
These photomicrographs show the differences in the shapes of typical natural and synthetic fibers that affect their properties and uses. The hollow center (lumen) of cotton can be clearly seen. The serrated edge of the rayon contrasts with circular nylon and wool. The scaly surface of the wool fiber does not appear in the cross-section.



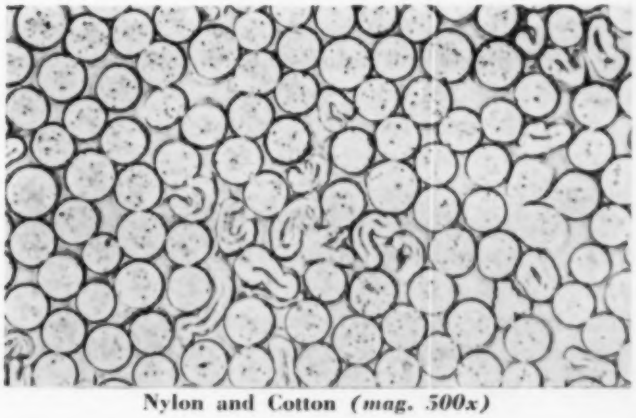
Mature Cotton ***(mag. 430x)***



Wool ***(mag. 250x)***



Viscose Rayon ***(mag. 430x)***



Nylon and Cotton ***(mag. 500x)***

Most attempts to control the shrinkage of wool have been based on smoothing the sharp edges of the scales by chemical means. The need for washable woolen goods during World War II accelerated research on this problem. Processes generally used are based on oxidizing agents, such as hypochlorite or permanganate, or on formaldehyde for cross-linking.

Problems of Blending Fibers

One of the major results of the development of the synthetics has been fabrics made from blends of different fibers. The high resistance to abrasion possessed by nylon has improved greatly the durability of fabrics chiefly composed of cotton or rayon. In this use, a little bit goes a long way. Men's cotton socks wear much longer when nylon is used with the cotton. Rayon slacks have become more extensively used with the help of nylon to increase the life of the cloth. Sweaters made of wool and nylon not only feel and look like wool, but can be washed like nylon.

Blends of each synthetic with each natural fiber, and with each other, are being eagerly studied by textile manufacturers. So far, only a few of the many possibilities have been put into production. Operations with these blends present many problems. One of the first resulted from the plastic nature of the synthetics. Early blends, processed as though they were composed only of natural fibers, often gave finished cloth which was badly wrinkled. The inability to prevent or remove these wrinkles seemed likely to destroy the potential value of the new cloth. However, the success in solving this problem showed a way to make fabrics which were quite resistant to becoming wrinkled when worn as clothing.

Since the wrinkles were caused by the plastic nature of the synthetic fiber, they could be pressed out by the proper combination of moisture, pressure, time, and temperature. Proper use of these conditions enabled textile and clothing manufacturers to place fairly permanent creases where desired, or to reduce the possibility of creases' forming.

The problem of dyeing is delaying many possible blends. The fibers react differently toward many dyes. Fabrics woven of yarns composed of different fibers can often be dyed two colors in one dye bath, which often changes a disadvantage into a very decorative advantage.

In developing blended fabrics, it is sometimes found that a given property of the basic fiber can be improved up to a certain point by addition of another fiber. Beyond this point, more harm than good may be done. For example, a cotton fabric can be made stronger and more abrasion-resistant by blending nylon with the cotton fibers. However, if too much nylon is used, the blended fabric is weaker than if it were all cotton. Although the exact reasons for this weakening effect are unknown, it must be considered carefully in preparing a new blend. A related problem involves the effects of blending more than two fibers. Will their good properties be additive, or will they offset each other? What proportions of each will give the best results? What proportions can be handled in a mill so as to have a uniform product? The consumer will gain by the answer to each such question.

In classes by themselves, at the present time, are glass fabrics and "nonwoven" fabrics. Glass yarn has high tensile strength, but low elasticity. This combination of properties makes it of little value for clothing, but of great value for laminated materials and certain types of draperies and curtains. The nonwoven fabrics are made without many of the high-cost operations necessary to make a woven fabric. Thin webs of fibers, held loosely together, are bonded into a fabric by resin impregnation. The finished material is not so strong as a woven one, nor does it drape in the most desirable manner. However, its cost makes it an attractive field of study. Perhaps some day sheets, dress material, and other clothing may be made of this type of goods.

Improving Natural Fibers

The consumer has become aware of some of the new properties of the synthetics. Many resist wrinkling or creasing, or hold a desired crease for some time. Their resistance to soiling is often greater than that of the natural fibers. Some synthetics burn less readily. Their water-resistance and quick-drying features are very attractive. Wind resistance and insulating properties have led to redesigned clothing. These particular properties have spurred research on the natural fibers.

Early attempts to improve these properties in fabrics made of the natural fibers were based on the physical addition of certain modifying agents. The resins, previously mentioned, improved wrinkle resistance and reduced shrinkage. Addition of certain modified starches and cellulose compounds changed the hand of a fabric and often made it more resistant to soiling. Flame resistance was obtained by addition of certain solid flame retardants, binding them in place by use of a resinous or film-forming substance. However, many of these processes resulted in undesirable loss of strength, weight increases, or stiffening of the fabric.

Certain of the resin processes and some water-repellent ones seemed to involve one or more chemical reactions between the fiber and the processing chemicals. This led to another approach to the problem of improving the natural fibers. Perhaps chemical changes

PROPERTIES OF SOME NATURAL AND SYNTHETIC TEXTILE MATERIALS

A general comparison of natural and synthetic fibers. The list of synthetics can be extended by variations in the basic structures or by various copolymerizations. Exact data are omitted because they generally depend on the test conditions used. The comparative terms used are those which might be used by an average consumer familiar with cotton, wool, and viscose rayon. Evaluations are based on yarns without oil, sizing, or other agents generally used during processing. None of these evaluations is to be construed as either exact or final.

Fiber	Chemical Composition	Tensile Strength	Elasticity	Water Absorption	Tendency to Shrink	Flammability[1]	Abrasion Resistance	Mildew Resistance	Insect Resistance	Weather Resistance	Chemical Resistance[4]		
											Acids	Alkalis	Chlorinated Solvents
Cotton	cellulose	good	poor	medium	high	flammable	poor	poor	good	poor	poor	good	good
Wool	keratin (protein)	variable	good	high	high	will burn	good	fair to good	poor	poor	fair	poor	good
Silk	fibroin (protein)	high	good	high	low	will burn	good	fair to good	good	poor	poor	fair	good
Viscose Rayon	regenerated cellulose	fair to good	poor	high	high	flammable	poor	poor	good	poor	poor	poor	good
Acetate Rayon (Estron)	cellulose acetate	fair to good	good	low to medium	fair	will burn	poor	good	good	poor	fair	poor	good
Nylon	hexamethylene diammonium diadipate	good	good	low	low	flame resistant	excellent	excellent	good	fair	fair[2]	good	good
Perlon	gamma-caprolactam	good	good	low	low	flame resistant	excellent	excellent	good	fair	fair[2]	good	good
Vinyon	vinyl chloride vinyl acetate	fair	fair	low	low	flame resistant	good	good	good	fair	good	good	fair
Vinyon N or Dynel	vinyl chloride acrylonitrile	fair	fair	low	low	flame resistant	good	good	good	fair	good	good	fair
Saran or Velon	vinylidene chloride, vinyl chloride	fair to good	fair to good	low	low	flame resistant	good	good	good	fair to good	good	good	good
Orlon	acrylonitrile	fair to good	fair to good	low	low	will burn	good	good	good	good	good	fair[2]	good
Dacron or Terylene	glycol ester of terephthalic acid	fair to good	good	low	fair	will burn	good	good	good	good	good	fair[2]	good
Acrilan	acrylonitrile and two other vinyl derivatives	fair to good	fair to good	low	low	probably flame resistant[3]	good	good	good	fair	fair[2]	fair[2]	good
Glass	glass	good	low	none	none	none	excellent	excellent	excellent	excellent	excellent	excellent	excellent
Vicara	zein (protein)	low	fair	medium	fair	will burn	low	good	good	fair	good	fair	good

[1] "Flammable": burns readily
"Will burn": burns slowly
"Flame-resistant": will stop burning if flame is removed

[2] Resistant to low concentrations at normal temperatures

[3] Classified by its chemical similarity to Dynel

[4] All fibers have good resistance to alcohols and oil except Vinyon and Dynel which are somewhat affected by oil

of the basic molecular structures would give the desired changes without the undesirable ones. Results so far obtained in this approach are promising. For example, flammability of cotton and rayon has been reduced by reacting the cellulose of each with urea and phosphoric acid. A slightly different reaction to reduce flammability has been the formation of a chelate between cellulose and certain titanium compounds. Water repellency is increased by chemically attaching certain hydrophobic compounds to cellulose, using pyridine to aid in the reaction. Partial acetylation of cotton cloth has improved its resistance to rotting, when in contact with the ground.

Many possible reactions are being studied. Because of the large quantity of cotton and rayon consumed, most of these studies are on reactions with cellulose. Desirable results have often been obtained with very little weight increase or change in draping qualities. However, losses in tensile strength have been serious. In such cases, the modified fabrics have sometimes been found to have new properties which make them useful where the loss in tensile strength is not a handicap.

Much fundamental research on textile fibers is needed. The works of Carothers, Mark, and many others have shown how large molecules can be made and then formed into filaments or fibers. Correlations are being sought among the molecular structures and the physical properties of fibers, yarns, and fabrics. More work on this approach is needed. It is desirable to relate the molecular and fiber structures to the resistance of the textiles to weather, organisms, flame, and chemicals. As more of these chemical and physical relationships become known, more and better fibers and fabrics can be made.

Some day we may have rayon fabrics which will dry as rapidly as nylon, and white shirts which will stay white; and we may be able to slide out of our cars without a startling electrical shock when we open the door. Through research, the textile industry is improving the qualities of its products and we can continue to expect better textiles for every purpose.

I think as a nation we must recognize that whatever the reward of the individual, it is small compared to the national benefits that accrue from his work . . . This is simply another way of saying that science does its best in a free society. In our universities we must have freedom of thought and expression—we must be free to work in whatever field we choose. In industry, our companies must be free to grow, and to harvest the fruits of their successes just as they are obligated to absorb their losses.

Industrial and academic science together must be free to question the old and embrace the new, to eliminate the wasteful, and to crown the efficient.—*Crawford H. Greenewalt, President of E. I. du Pont de Nemours and Company, Inc., on receiving the 1952 medal of the Society of Chemical Industry*

Search for High-Temperature Materials

by William L. Bruckart

Since becoming a member of the Battelle staff in 1947, the author has carried on research on molybdenum and molybdenum alloys for use in jet engine and atomic energy applications. Several of his papers have been published in Iron Age *and the* Transactions of the American Society for Metals. *Bruckart is a graduate of the University of Kentucky in metallurgical engineering. He is a member of the American Society for Metals and Sigma Xi.*

Power plants operating at high temperature present probably the most severe conditions for materials of construction. Beginning with the steam boiler, men have been constantly striving toward higher operating temperatures so that advantage might be taken of the resulting increased thermal efficiency. Today, a tremendous effort is being put forth to find suitable materials to use at temperatures above 1600 F.

While designers are dreaming of engines to operate at temperatures of 2600 F and even higher, the materials engineers are finding increasing difficulty in creating and selecting combinations of metals and ceramics to fit the dreams. Even with special devices such as sweat cooling built into the designs, the problem is mitigated but little because of the added complexity and weight. As the service temperature is raised, the number of materials possible for selection become fewer because of melting point limitations alone. In addition, such factors as availability, chemical stability in the presence of other materials, oxidation resistance, strength, fabricability, and methods of joining all become critical at these temperatures. Strength at high temperature with easy fabrication presents somewhat of a paradox in that materials so highly resistant to deformation are very difficult to work by conventional methods.

Ceramics

Ceramic materials, including carbon, have shown great promise in a number of applications. Much effort is being expended to apply these materials wherever ductility and impact resistance are not so critical. This research has resulted in the use of ceramic linings for rocket motors and in the development of "cermets" that are giving some encouragement in turbine blade applications. "Cermets" are metal-ceramic mixtures such as metal-bonded titanium carbide. One method proposed to overcome the brittleness of ceramic and cermet components is to apply a compression stress. It is felt that even aircraft wings could be made of ceramics if they were designed to be under compression.

There are numerous high-temperature applications where sheet products are required. Only metals can provide the necessary formability and ductility, and there are few metals which possess the strength and oxidation resistance for such an application. In the region from 1600 to 2000 F, low-strength requirements can be met by the oxidation-resistant iron-chromium-nickel and cobalt-base alloys. These alloys are composed of several materials that are in critically short supply.

Promise of Molybdenum

For applications requiring higher strength, molybdenum, with a melting point of 4760 F, has been found most promising. A consideration of all of the possible high-melting metals reveals that this metal and its alloys offer the only satisfactory answer to the problem of availability in quantity, strength at elevated temperature, and ease of fabrication. It is subject to oxidation which becomes appreciably high at 900 to 1000 F. At higher temperatures, the rate is catastrophic, and the metal is useless unless protected.

A number of methods for protecting molybdenum have been developed successfully. For the highest temperatures, say to 3300 F, one can now use siliconized molybdenum. This product is made by vapor depositing a very thin layer of silicon onto the hot surface of molybdenum and also by the paint-on and sinter method. The extreme brittleness of this coating causes it to crack easily when struck or deformed. Nevertheless the coating is the best for extreme temperatures.

Cladding by the rolling-on method has been known for some time. Its application to the protection of molybdenum has been particularly successful when nickel and nickel-base alloys are used. One advantage of the use of nickel for such protection is that small defects in the cladding will not destroy the protection.

It has been found that oxidation at such defects occurs very slowly. Cladding molybdenum with ductile metallic coatings offers other advantages. The clad molybdenum may be shaped and is also resistant to mechanical and thermal shock.

Other methods of protecting molybdenum are being investigated. Such methods as alloying, coating with ceramics, and stabilization of surface oxides by the use of other oxides and intermetallics are being explored.

Molybdenum Alloys and Other Metals

The strength of molybdenum at room temperature is not outstanding, being comparable to that of mild steel. Strength may be increased by cold-working to a fibered structure. As temperature is increased, the rate of loss of strength is less in molybdenum than in well-known high-temperature materials such as Vitallium. Above 1600 F, molybdenum shows a superior set of properties which persist until the recrystallization temperature of about 1800-2200 F is reached. Recrystallization results in a loss of about half the strength. Even after recrystallization, the strength of molybdenum at higher temperatures is greater than that of any of the other commercially available wrought materials.

Recent data indicate that the promise of molybdenum as a high-temperature material is enhanced by alloying. The elements aluminum, chromium, columbium, silicon, titanium, tungsten, and vanadium all improve the strength of molybdenum at both room and elevated temperatures. For example, a properly protected molybdenum 0.25 per cent silicon alloy developed at Battelle has been tested at 1800 F and 25,000-psi stress. It lasted nearly 300 hours with a minimum creep rate of 0.014 per cent per hour. This is superior to the life of any of the commercial high-temperature alloys under these conditions of temperature and stress.

When considering high-temperature materials, one must not neglect the potential uses of such metals as chromium, columbium, tantalum, and tungsten. With the exception of chromium, these elements are not available in great quantities. However, they do offer possibilities for special small parts where unusual conditions must be met. Current investigations, principally with chromium, include studies of means to produce workable high-temperature alloys from these metals.

Problem of Joining

Problems of joining metals for high-temperature service become acute as the temperature is raised to the region above 1600 F. This phase of high-temperature material development is receiving much attention by investigators. Mechanical joints are limited in application because creep and oxidation in the metals often cause the joints to loosen. Welded joints are not wholly satisfactory at this stage because in molybdenum, for example, the heat necessary to make the joint would cause recrystallization to occur. The recrystallized structure in turn would be weak, and probably brittle at room temperature. Brazing and braze welding are being investigated along with welding as possible means of joining. It is possible that a combination braze-welded mechanical joint will be one of the answers to this problem.

This discussion has described results of research covering the past 5 to 10 years. Many of the problems worked on during that period have been solved. However, many new ones have arisen. It could be that in another ten years the ceramic and metallurgical sciences will have developed useful high-temperature materials which are not yet conceived.

It has been the experience of our laboratory that the search for knowledge in new fields by those who are alert to the possible applications, frequently leads to new discoveries. The word, serendipity, coined two centuries ago by Horace Walpole, well describes this situation. Serendipity may be defined as "the art of profiting from unexpected occurrences." Much of the progress, not only in research laboratories but in the world as a whole, depends on serendipity rather than on careful planning directed toward specific ends.—*Irving Langmuir in* Phenomena, Atoms and Molecules

Notes From Battelle

REFRACTORY THAT RESISTS HEAT SHOCK

A method of producing a new refractory material that shows no spalling, erosion, fusion, or cracking, even when suddenly heated to temperatures up to 3700 F, is now available. This material is produced from a mixture of aluminum and alumina and has good thermal-shock resistance and strength. It was developed at Battelle in connection with ceramics research that was conducted for the Air Force.

The process involves the mixing of finely divided alumina and aluminum together with enough binder to give the pressed body sufficient "green" strength to retain its shape when handled. After molding, the body is placed in a graphite crucible and completely covered with finely divided graphite which is tamped around the body. This container is then placed inside a second, larger clay-graphite crucible and is also surrounded by finely divided graphite which is tamped thoroughly. The entire assembly is then heated to sintering temperatures in air. The superior properties of the material appear to develop during the sintering and are probably the result of aluminum nitride formation and possibly of carbon and minor amounts of aluminum oxide. The resulting material has a modulus of rupture ranging from 800 to 12,400 psi.

Possible uses for this refractory material include linings for exhaust parts of engines and for fuel-burning chambers, and for protection of structural metallic parts and catalytic reactors.

COMBATING BOILER CORROSION

The mercury boiler at the Hartford Light Company's South Meadow Station has two separate heat-conversion cycles. In one, the thermodynamic fluid is mercury; in the other it is water. The boiler is tubed with Sircomo 5S steel containing 5 per cent chromium, 1.5 per cent silicon, and 0.5 per cent molybdenum, together with low carbon and nominal amounts of manganese, sulfur, and phosphorus. A heavy residual oil is used as fuel.

Shortly after a shift was made to South American oil, a wastage was noted on the external surface of the tubes where skin-metal temperatures were above 1150 F. The fuel oil was known to contain sodium and to be relatively high in sulfur and vanadium. It was therefore thought reasonable to suppose that a low-melting mixture of these elements in oxidized form might be causing the wastage of the tubes.

Battelle technologists were called in to find ways of reducing tube wastage by means of protective coatings and of reducing the corrosiveness of the combustion products of the fuel by means of additives.

Investigation showed that coatings of 26 per cent chrome-iron and aluminum held considerable promise. The metallic coatings can be sprayed on after the tubes have been carefully cleaned. Best results seemed to come from putting the aluminum coating over the 26 per cent chrome-iron coating.

Laboratory tests showed that tube corrosion was lessened by adding calcium soap derived from tall oil to the fuel. When the soap was added to the fuel oil in the ratio of three atoms of calcium in the tallate to one atom of vanadium in the fuel, it was shown that corrosion might be reduced as much as 40 per cent.

NEW PLANT-GROWTH REGULATOR

A new compound, known as CDAA, is joining a growing family of plant-growth regulators. These growth regulators operate by counteracting the hormones that control the growth of the plant system. Nature supplies different hormones to promote the growth of various parts of a plant. A job of the plant-growth regulator is to restrict temporarily the hormones that induce the growth of one part of the plant system, such as the main stem or the buds, without affecting the growth of other parts.

Plant-growth regulators can be of importance to farmers, horticulturists, and fruit and vegetable processors. The regulators may hold the key to the protection of budding plants against frost. They are already being used to prevent fruit drop before harvest time and undesirable growth of vegetable plants during storage or shipment.

CDAA, more technically known as 2-cyano-3-(2,4-dichlorophenyl) acrylic acid (Ethyl-214), is being studied by Russell E. Hay and Donald P. Uhl of Battelle and W. B. Ligett and Calvin N. Wolf of the Ethyl Corporation Research Laboratories, Detroit, Michigan. They report: "When applied at low concentrations, this compound produced the striking effects of inhibiting the growth of the main stem of tomato plants and the flowering of marigolds. These results were achieved without visible injury to the plants and without an over-all slow-down of growth." They also pointed out that the use of CDAA is not limited to these plants. Tomato and marigold were

selected because they are easy to grow in a greenhouse and thus permit year-round growth.

SUBSTITUTION BY PLANNING

"Substitution on the whole is a mark of industrial progress and involves the development of a tailor-made product for a specific end use," stated John D. Sullivan in a paper before the Manufacturing Conference of the American Management Association at Cleveland. The Battelle assistant director pointed out that substitutes often do a better job than the original or are cheaper to use.

In his paper, Sullivan analyzed the nature of substitution, listing nine major classifications. These include substitution: by geographic change of location of plant or source of raw materials supply; by change in processing; by change of kind of raw materials; by development of new products; by development of new processes; for economic reasons; because the substitute does a better job; of necessity; and by changing requirements.

The storage of energy is an exceptionally interesting type of substitution. During World War II, the production of magnesium was expedited by producing ferrosilicon where supplies of alternating current were available. The ferrosilicon was then moved to the sources of dolomite, where the magnesium was produced. In this way, the equivalent of electric energy was stored in a solid.

TITANIUM WELDING

As more uses are found for titanium, the need for welding the metal also increases. Since the presence of carbon, oxygen, and nitrogen affect the strength and ductility of titanium welds, the Air Materiel Command initiated an investigation at Battelle on the effects of these elements on welds in titanium sheet.

Most of the inert-gas-shielded-arc welding was done in a controlled-atmosphere chamber. The tests were made on both unalloyed iodide- and unalloyed sponge-titanium sheet, as well as on alloyed sheet. The properties of welds in both were about the same as the properties of the unwelded base metal.

The studies showed that alloys containing up to 0.13 per cent carbon have good weldability. Above that level, the carbon begins to have an adverse effect on the ductility of both arc and spot welds. At 0.55 per cent carbon, the bend ductility of arc welds is practically zero. Oxygen begins to have an adverse effect on welds at lower concentrations than carbon. Arc welds in titanium containing more than about 0.15 per cent oxygen have low ductility.

Nitrogen has a more adverse effect than either of the other two elements. Arc welds in titanium sheet that contain 0.13 per cent of nitrogen have very low bend ductility. When the nitrogen content reaches 0.24 per cent, arc-welded specimens have no ductility either in bend or tension tests.

The investigation emphasizes that the shielding of titanium from air during arc welding is very necessary. The shielding of spot welds is less critical because there is much less chance of contamination of the weld by the air.

NEW APPOINTMENTS

Three Battelle technologists have received appointments to supervisory positions. HAROLD W. LOWNIE, JR. became a supervisor in the Institute's process metallurgy laboratories. In his new position, Lownie supervises much of Battelle's research related to foundry practice and ore reduction. He is active in the committee work of the Gray Iron Division of the American Foundrymen's Society and has served on division committees on test-bar design, executive matters, and revision of the AFS Cast Metals Handbook.

WILLIAM L. SWAGER, a member of the Battelle staff since 1948, has been named to supervise and coordinate the Institute's expanding work in operations research. In this capacity, he will be responsible for the application of scientific technique and engineering methods to the operational problems of both industry and the military services. A graduate of Purdue University, he was associated with the Allied Chemical and Dye Corporation before joining Battelle.

DR. RAY E. HEIKS has been appointed to supervise Battelle's solid-state chemistry laboratories. In his new position he directs a research group studying the chemical aspects of semiconductor materials. In his ten years on the Battelle staff, he has been active in research on the chemistry of selenium, anti-fouling materials, and wood preservatives. He is a member of the Forest Products Research Society, the Marine Borer's Conference, and the Seahorse Institute.

RECENT PAPERS AND ARTICLES BY THE RESEARCH STAFF*

Radioactive Spot Makes Tachometer for High-Temperature Use. R. L. Belcher, *Chemical Engineering*, December, 1952.

A Cantilever Microtome for Precision Sectioning in Electron and Light Microscopy. G. G. Cocks and C. M. Schwartz. *Review of Scientific Instruments*, November, 1952.

Design of Flat-Wound Tension Springs. R. M. Conklin and D. R. Forry. *Product Engineering*, Annual Handbook of Product Design, 1953.

Nature of the Line Markings in Titanium and Alpha Titanium Alloys. C. M. Craighead, G. A. Lenning, and R. I. Jaffee. *Journal of Metals*, December, 1952.

Electropolishing. C. L. Faust. *Metals Finishing*, Guidebook-Directory Issue, 1953.

Microconstituents in Chromium-Base Chromium-Iron-Molydbenum Alloys and Their Behavior with Heat Treatment. J. P. Hammond, A. B. Westerman, and H. C. Cross. *Journal of Metals*, December, 1952.

What is Coal's Destiny? R. A. Sherman. *Western Miner*, November, 1952.

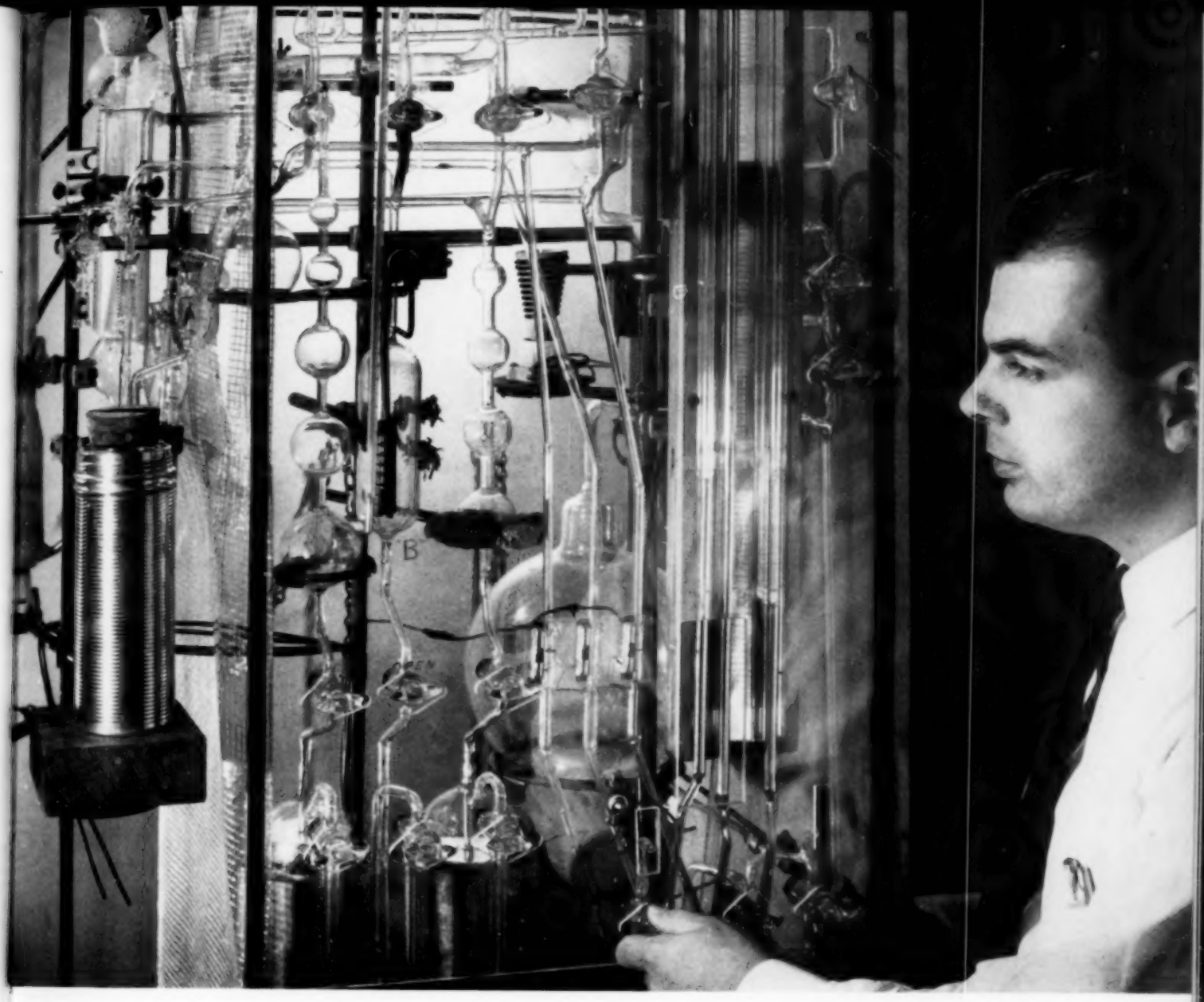
The Technique of Translation. L. M. Virtue and N. W. Baklanoff. *Modern Language Journal*, December, 1952.

Letterpress Printing Needs Improved Photoengraving Techniques. J. H. Winkler. *Spotting the News*. The Southeastern Photoengravers Association, October, 1952.

*In most cases, reprints will be available from the Battelle Publications Office upon request.

A Word About Battelle Technical Review Abstracts

The abstracts that appear in the following pages are prepared from approximately 950 American and foreign technical journals, as well as from books and other literature received in the Battelle Library. Prepared by a professional staff trained in various technological fields, the abstracts are selected for their usefulness to the Battelle research staff. They are now being made available to technologists and scientists in industry and research in all parts of the world, through the pages of the *Battelle Technical Review*.



ADSORPTION STUDY

This apparatus is used in the study of the surface structure and chemistry of materials. With it the scientist can determine the true surface area of powdered and porous materials and the distribution of surface in the minute pores of a solid. Some of its uses at Battelle have been a study of the adsorption of gases by catalysts, a fundamental study of the selectivity of carbon, and the measurement of gas desorbed by firebrick.

BATTELLE INSTITUTE was founded by the will of Gordon Battelle as a memorial to the Battelle family. The Battelles were among the first settlers of Ohio and were prominent in the development of the state's iron and steel industry.

Gordon Battelle, last of the family line, was impressed with the benefits to be derived from industrial research and left his estate for the building and endowment of an Institute "for the purpose of education . . . the encouragement of research . . . and the making of discoveries and inventions for industry." The Institute began operations in 1929.

As established Battelle provides, on a not-for-profit basis, the physical plant, equipment, and personnel for conducting research. The great bulk of it is applied research conducted for industry and government.

In keeping with its educational function, the Institute also conducts fundamental or basic research. The results of much of this research are published for the general encouragement of science and industry, and to benefit the public welfare.

Fields of research at Battelle include agriculture and practically all the industrial and engineering sciences.

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